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ABSTRACT

This study investigated the effectiveness of a schema strategy on the addition and subtraction word problem solving performance of four sixth and seventh grade students with learning disabilities. Students were taught to map features of the word problem onto problem schemata diagrams, first for one-step problems and then for two-step problems. A multiple-baseline design across students and across two behaviors was used. Results indicated that the schema strategy led to increases in the percentage correct of operations and computation solutions to word problems. Further, these results were maintained at 2- and 4-week follow-up, and all four students' performance on two-step word problems (mean of 86 percent correct) at the end of the study surpassed that of the normative sample (mean of 54 percent correct). Generalization of strategy effects was found for three of the four students. Student treatment acceptability ratings revealed that the strategy was perceived as helpful in solving word problems. (Author/DB)

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The Role of Schema-Based Instruction on Solving Multistep Word Problems

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Abstract

The present study investigated the effectiveness of a schema strategy on the mathematical word problem solving performance of 4 sixth and seventh grade students (2 girls, 2 boys) with learning disabilities. A multiple-baseline across-students and across-two behaviors design was used. Results indicated that the schema strategy led to increases in the percentage correct of operations and computation solutions to word problems. Further, these results were maintained at a 2 and 4 week follow-up, and all four students' performance on two-step word problems (M = 86% correct) at the end of the study surpassed that of the normative sample (M = 54% correct). Student treatment acceptability ratings revealed that the strategy was helpful in solving word problems.

Purpose of the Study

The purpose of this study was to extend the previous research on word problem solving using a schema strategy by investigating the generalization of the strategy effects from one-step to two-step addition and subtraction word problems and to the classroom setting by middle school students with learning disabilities. In addition, the study intended to examine the effects of the schema strategy in solving two-step word problems and the maintenance of the strategy effects over time.

Methodology

Participants

Four middle school students with learning disabilities (Janet, John, Peter, and Mary) were selected based on several criteria. First, students were deemed to be poor word problem solvers as judged by their teachers. Second, each student had to complete a mathematics skills test that involved: (a) 20 addition and subtraction problems involving regrouping and no regrouping, (b) 3 simple action problems that required phrase by phrase translation, and (c) a sample of 14 one-step addition and subtraction word problems involving regrouping and no regrouping. In addition, we included 21 normally achieving third grade students for testing only. The third graders were administered three 10-item word problem tests identical to the probes used in the study at specified intervals. The first test was administered at the beginning of the study and served as a pretest. The remaining two tests were given following instruction on one-step and two-step word problems for Janet.

Dependent Measure Materials

Word Problems. Word problem probes consisted of three different problem types (i.e., change, group, and compare) based on Riley et al. (1983) word problem classification system. Each probe contained six one-step and four two-step problems requiring addition and subtraction operations. All word problems were scored to permit demonstration of student understanding (percentage correct operations) and accuracy (percentage correct operation and computation) in solving problems. Scores for one-step problems ranged from 0 to 2, while scores for two-step problems ranged from 0 to 4.

Strategy Questionnaire. Students completed a strategy questionnaire interview at the end of the study that provided information on each student's perception of strategy effectiveness, acceptability, and satisfaction in solving word problems (see Table 1).

Strategy Usage. All completed probe worksheets were scrutinized for presence of schemata diagrams, diagram mapping, and application of taught rule (i.e., writing the total) to assess the extent to which students used the schema strategy. Student conceptual understanding of word problems was assessed by examining the diagrams and the mapping procedure used to represent the word problems, while procedural knowledge was assessed by examining whether or not students used the taught rule to correctly identify the total needed to find the solution.

Intervention Materials

Materials included scripted lessons for teaching one-step and two-step word problems, strategy diagram sheets, and numerous practice problems designed for this phase of the study. In addition, story situations that did not involve any unknown information were developed for use in teaching students to discern the three different problem types (change, group, compare). Worksheets with story situations included problem schemata diagrams for the three different problem types. Additional materials included note sheets with strategy rules for identifying the total and the operation to use in solving word problems.

Experimental design

A multiple-baseline across-subjects and across-two behaviors design was used to demonstrate the effects of the schema strategy in teaching word problem solving processes to students with learning disabilities. The experimental phases included baseline, two levels of instruction and post instructional probes, setting and behavior generalization, and maintenance.

Procedures

Baseline Procedure. All students were provided with worksheets containing 10 word problems (6 one-step and 4 two-step). Students were told to do their best, show all their work in the space provided, and write the complete answer on the line at the end of the problem. In addition, they were encouraged to call on the examiner if they experienced difficulty with individual words in the problems.

Instructional Procedures. Schema training procedures in this study were criterion based and required students to reach 90% criterion for 2 days prior to progressing to the next instructional phase and/or level.

One-Step Word Problems. During the first phase of schema strategy training, students were taught to distinguish the unique features of each problem type (change, group, and compare) in story situations that did not contain any unknown information. Schemata diagrams were provided to allow students to

map features of the story situation onto the diagrams (see Figure 1). Once students displayed knowledge of problem schemata, the second phase of training began. Students were provided with a review of the problem schemata, but in the context of word problems rather than story situations. Additionally, the strategy mapping instruction required flagging the missing element in the problem with a question mark. Instruction then proceeded to an explanation pertaining to finding the object identity that represented the total amount in the word problem by focusing on the specific information provided in the verbal text.

Next, students were taught a generalizable rule for determining the correct operation by examining the part of the situation that was unknown and whether or not it represented the total amount. For example, "When the total is not known, we add to find the total; when the total is known, we subtract to find the other amount."

At the end of each session in both training phases, students completed a worksheet either containing story situations or word problems. Upon completion, the worksheet was checked and appropriate feedback was provided. Finally, students were administered 10-item word problem probes immediately following instruction on one-step word problems.

Two-step Word Problems. Problem-solving instruction for two-step word problems employed the same general procedures (e.g., explicit and overt teacher modeling and guided practice) as those for one-step problems. However, unlike one-step problem solving, instruction focused on chaining two schemata. Initially, istruction involved having the learner identify the overall or primary problem schema to be solved. Primary schema identification was taught by having students focus on the question asked in the problem and by examining the surrounding context (e.g., Barbara and Vicki decided to see who would lose the most weight in one month. Barbara lost a total of 10 lbs. Vicki lost more weight than Barbara and went from 160 lbs to 125 lbs. How much more weight did Vicki lose than Barbara?). Next, students were taught to identify the secondary problem that must be solved to answer the primary problem. In essence, "chaining occurs through the use in the second schema of a set from the first" (Goldman, 1989, p. 53). Figure 2 illustrates solving two-step word problems using the schema strategy. Again, student were administered 10-item word problem probes immediately following instruction on two-step word problems.

Generalization and Maintenance Procedures. The special education teachers in the resource rooms administered a word problem probe in their classrooms to determine generalization of the strategy under

typical classroom conditions. This probe was completed by students at the end of the first instructional level, schema instruction on one-step word problems. In addition, generalization of strategy effects to more complex word problems (two-step) was determined by the inclusion of two-step word problems in the word problem probes. To assess maintenance of the strategy effects, all students were administered two probes at the end of 2 and 4 weeks following the completion of the second instructional level, instruction on two-step word problems. Procedures for administering the probes were identical to those in baseline and postinstructional probes conditions.

Results

Mean Percentage of One-Step and Two-Step Math Word Problems Correctly Completed

Students	Baseline		Level 1[a]		Level 1[b]		Generalization		Maintenance	
	O-S[c]	T-S[d]	O-S[c]	T-S[d]	O-S[c]	T-S[d]	O-S[c]	T-S[d]	O-S[c]	T-S[d]
Janet	72	38	89	71	88	84	83	63	100	91
John	53	25	75	73	75	88	67	81	79	78
Peter	50	3	67	6	79	94	64	0	83	63
Mary	47	0	67	27	96	78	83	38	79	88
3rd Graders	49	26	67	55	85	54				

Note: [a]Probes completed following instruction in using the strategy with one-step word problems; [b]Probes completed following instruction in using the strategy with two-step word problems; [c]O-S = One-step word problems; [d]T-S = Two-Step Word Problems.

In addition, Figure 3 presents a visual display of the percentage correct operations and computations for one-step and two-step word problems.

Strategy Use

Table 2 presents the percentage of time students displayed overt use of the strategy steps (i.e., diagramming, mapping diagrams, and noting the total) when completing the probes during each phase of the study.

Strategy Questionnaire Interviews

Table 1 presents findings from the strategy questionnaire.

Discussion

The results of this study indicate that the schema strategy facilitated solution of both one-step and two-step addition and subtraction word problems and reduced errors resulting from applying the incorrect operation for the four students with learning disabilities. Interestingly, all students' mean scores on two step word problems surpassed those of the normally achieving third graders, thus validating the social significance of the amount of improvement made by the students with learning disabilities. Generalization of the strategy effects was also noted following training in one-step word problems for three of the 4 students. Improvements over baseline scores for both one-step and two-step word problems were maintained on 2 and 4 week follow-up probes for all students. Although improvements over baseline were consistently maintained at follow-up, post instructional performance was inconsistently maintained. A plausible explanation is that students were tired of the excessive testing or were less careful in following the strategy steps as was the case with Peter. Furthermore, students' responses to the strategy questionnaire were positive indicating the relevance of the strategy instruction for improving their word solving performance.

Several considerations limit the generalizability of the findings in this study. First, students in this study were middle school students in grades significantly beyond the grade level where these skills are typically taught. Second, instruction occurred individually outside of a classroom environment using controlled materials. Third, maintenance of learned skills was assessed at 2 and 4 weeks after instruction, which was only a week longer than that of the Jitendra and Hoff (1996) study.

References

Jitendra, A. K., & Hoff, K. (1996). The effect of schema-based instruction on mathematical word problem solving performance of students with learning disabilities. Journal of Learning Disabilities, 29, 422-431.

Marshall, S. P., Barthuli, K. E., Brewer, M. A., & Rose, F. E. (1989). STORY PROBLEM SOLVER: A schema-based system of instruction (CRMSE Tech. Rep. No. 89-01). San Diego, CA: Center for Research in Mathematics and Science Education.

Table 1

Individual Strategy Questionnaire Ratings

	Janet	John	Peter	Mary
I. Strategy Effectiveness (Scale of 5 to 1, with 5 being the most helpful and 1 being the least helpful)				
A. The strategy helped me solve word problems.	5	5	4	5
B. The change, group, and compare diagrams were helpful in understanding the problem.	5	5	5	5
C. Placing the parts of the problem in the diagram and labeling them helped me to better solve the problem.	5	4	5	5
D. The rules to find the total and determine whether to add or subtract to solve the problem was useful.	4	5	3	5
E. The note sheets helped me with solving the word problems.	4	2	3	3
II. Strategy Application				
A. How often (e.g., 4 = very often, 3 = often, 2 = at times, 1 = never) would you use the strategy to solve addition and subtraction problems in your classroom?	3	3	2	3

Table 1

Individual Strategy Questionnaire Ratings (Continued)

III. Strategy Satisfaction				
A. Would you recommend this strategy to someone in your class? YES or NO	Yes	Yes	Yes	Yes
B. How strongly (4 = very strongly, 3 = quite strongly, 2 = somewhat strongly, and 1 = not strongly) would you recommend this strategy?	4	2	3	3
C. What did you like most about solving word problems in this study?	• Solving change problems • Using the diagrams	• Finding the total • Solving the change problems	• Getting correct answers	• Working with the instructors • It was fun
D. What did you like least about solving word problems in this study?	• Finding the total • Too many problems	• The words in the problem • Too many problems	• Solving compare and two-step problems • Too many problems	• Nothing • Too many problems

Table 3

Percentage of Time Students Displayed Overt Use of Strategy Steps

Condition	Baseline		Level 1[a]		Generalization		Level 2[b]		Maintenance	
	One-step	Two-step	One-step	Two-step	One-step	Two-step	One-step	Two-step	One-step	Two-step
Janet										
Draw diagrams	0	0	50	0	33	38	100	75	100	88
Map diagrams	0	0	50	0	33	38	100	75	100	88
Write the total	0	0	0	0	0	0	58	25	50	38
John										
Draw diagrams	0	0	100	50	100	38	100	88	100	88
Map diagrams	0	0	100	50	100	38	100	88	100	88
Write the total	0	0	92	19	83	38	100	56	83	50
Peter										
Draw diagrams	0	0	100	50	100	25	100	100	100	69
Map diagrams	0	0	92	44	100	25	100	100	100	69
Write the total	0	0	42	0	83	6	92	75	83	50
Mary										
Draw diagrams	0	0	100	94	100	50	100	94	100	63
Map diagrams	0	0	100	94	100	50	100	94	100	63
Write the total	0	0	100	88	33	0	58	44	100	25

Note. Percentages were computed by dividing the number of times the strategy step was written by the total number of possible times; [a]Probes completed following instruction in using the strategy with one-step word problems; [b]Probes completed following instruction in using the strategy with two-step word problems

Figure Captions

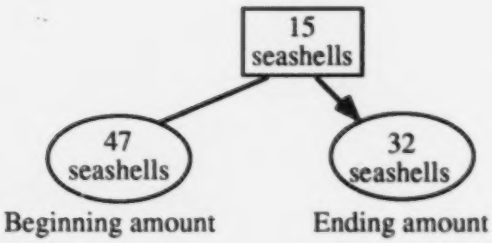
Figure 1. Sample story situations and schemata diagrams for change, group, and compare problem type. Representation adapted from "Schema knowledge structures for representing and understanding arithmetic story problems" by Marshall, S. P., Barthuli, K. E., Brewer, M. A., and Rose, F. E. in CRMSE Tech. Rep. Contract No. 89-01, 1989, San Diego, CA: Center for Research in Mathematics and Science Education.

Figure 2. Sample procedure for solving two-step word problems.

Figure 3. Percentage correct operations and computations for one-step and two-step word problems.

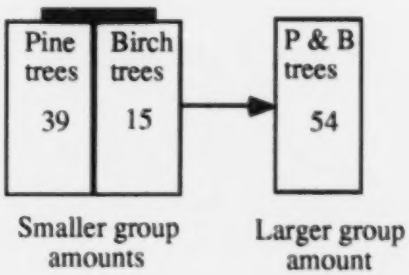
Change Story Situation

Janet had 47 seashells. Then she lost 15 of them while moving. Now Janet has 32 seashells.



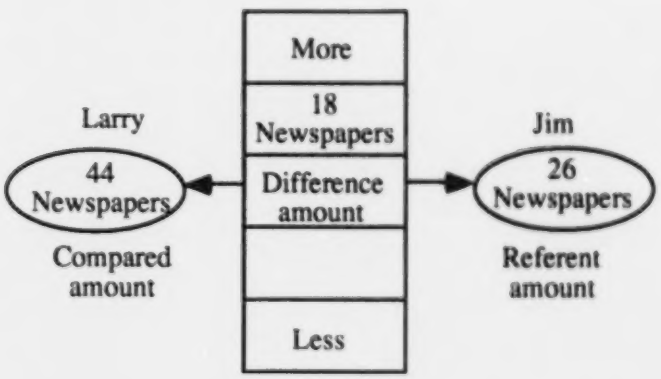
Group Story Situation

Kay owns a nursery that has 54 trees. 39 are pine trees and the remaining 15 are birch trees.



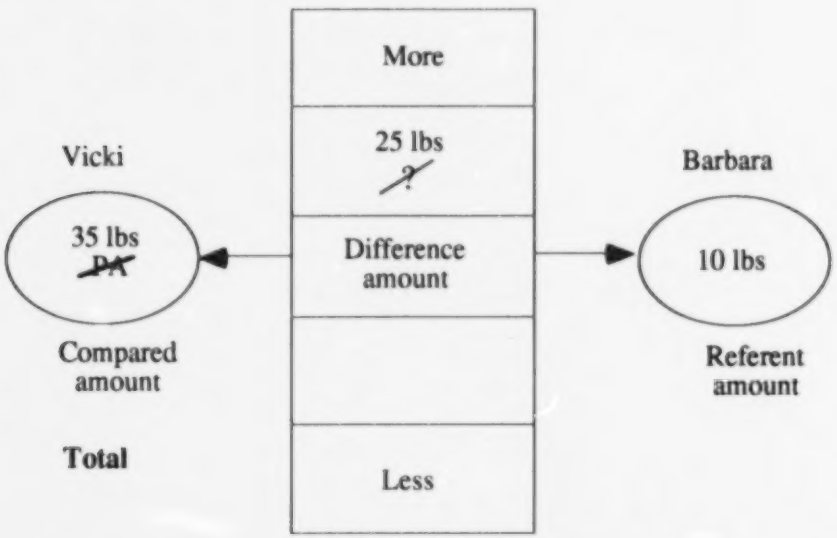
Compare Story Situation

Jim delivered 26 newspapers on Monday. His friend Larry delivered 44 newspapers. Larry delivered 18 more newspapers than Jim.

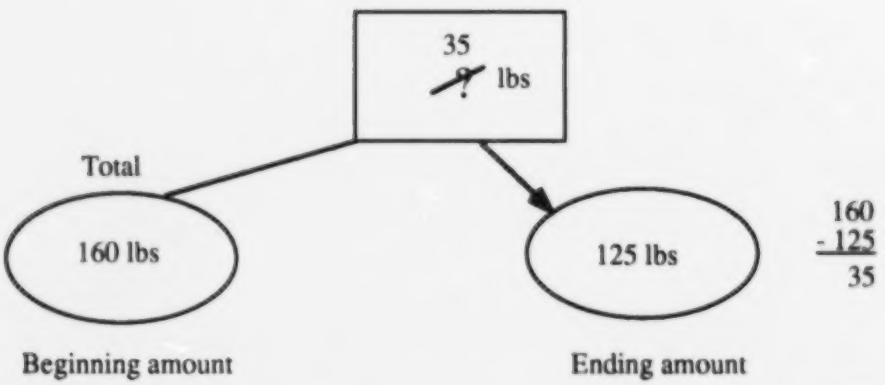


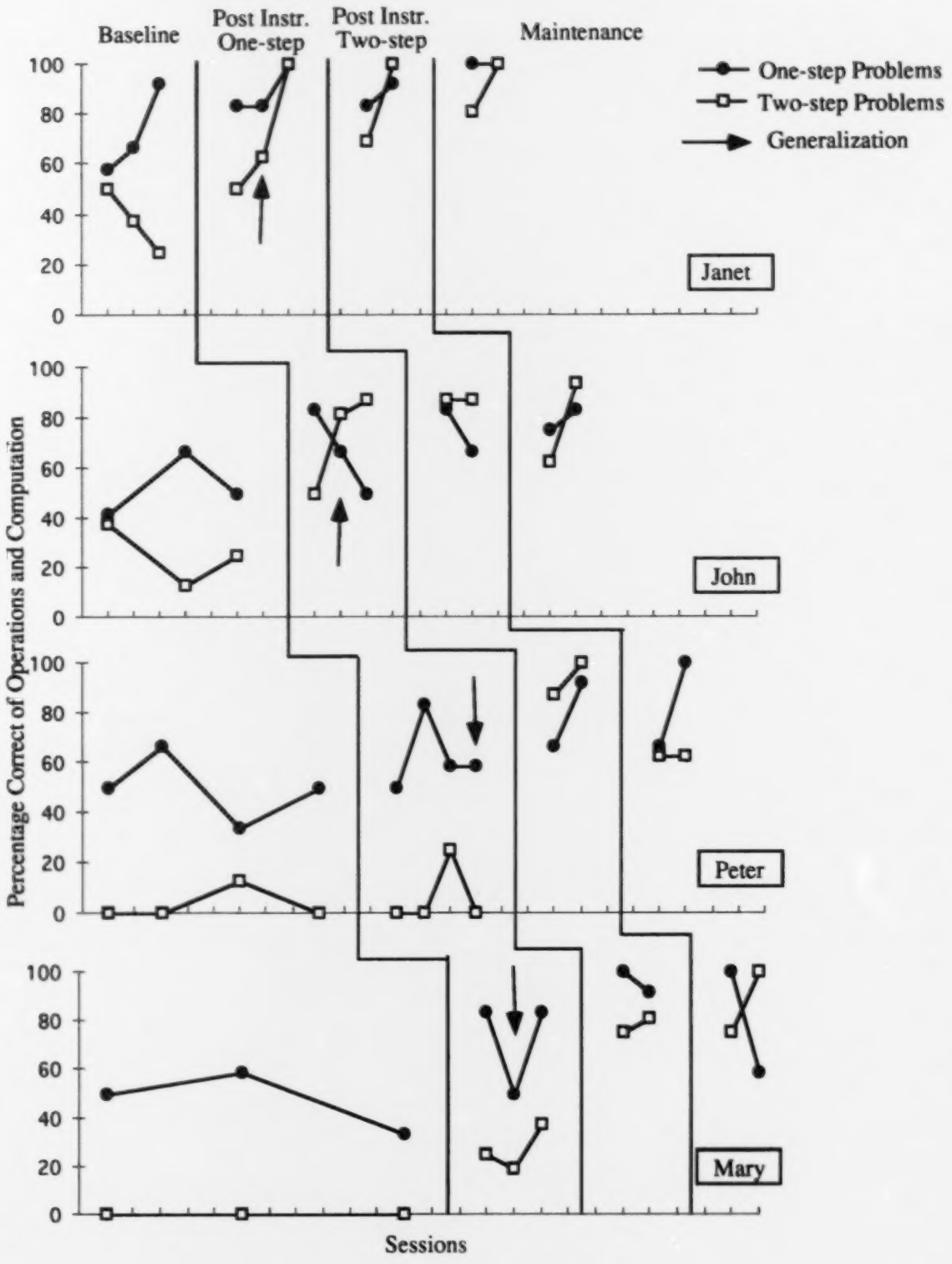
Two-Step Word Problem: Barbara and Vicki decided to see who would lose the most weight in one month. Barbara lost a total of 10 lbs. Vicki lost more weight than Barbara and went from 160 lbs to 125 lbs. How much more weight did Vicki lose than Barbara?

Primary Problem: Compare



Secondary Problem: Change




Baseline
Post Instr. One-step
Post Instr. Two-step
Maintenance
One-step Problems
Two-step Problems
Generalization
Janet
John
Peter
Mary
Percentage Correct of Operations and Computation
Sessions
0
20
40
60
80
100